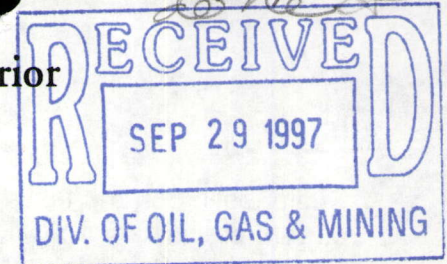




# United States Department of the Interior

BUREAU OF LAND MANAGEMENT

Moab District Office  
82 East Dogwood Ave.  
Moab, Utah 84532



UTU-72499  
(UT-060)

SEP 25 1997

*M/037/088*

ALT  
9/25/97

Mr. Bob Prescott  
Summo USA Corporation  
P.O. Box 847  
Moab, UT 84532

Dear Mr. Prescott:

The purpose of this letter is to confirm the details of waste-rock testing protocol and additional Navajo aquifer test wells to be completed by Summo as discussed during the meeting of September 12, 1997 in Moab, the telephone conference call between BLM and Summo representatives on September 16, 1997, and the field trip to the project site on September 17, 1997 involving BLM, Summo, and Adrien Brown Consultants.

This data collection activity is consistent with requirements for additional characterization efforts identified in and authorized by the March 26, 1997 Record of Decision (ROD) approving the Lisbon Valley Copper project, (ROD at pp. 20-24). This work is also allowed under authority of the June 16, 1997 Interior Board of Land Appeals Order on appeal of that ROD, (IBLA 97-339).

Data from these testing efforts will allow additional characterization of geochemical properties of the waste rock associated with the mining operation, in addition to providing more complete information regarding hydrologic characteristics of the Navajo aquifer in the project vicinity.

## 1- Geochemical Waste-Rock Sampling

Four major rock types were identified by the company that make up 76% of the total waste rock:

- Alluvium - 7.7 million tons
- Mancos Shale - 24 million tons
- Dakota Formation, beds 11, 12, and 13 - 14.8 million tons
- Burro Canyon Formation, bed 14 - 24 million tons

Three samples of each waste-rock type will be collected from each pit site for solid-phase chemical analysis and Meteoric Water Mobility Procedure (MWMP) testing. The company has proposed that it drill three reverse-circulation drill holes per pit to collect these samples. This method of sample collection is common practice and is acceptable to BLM. Summo has provided clarification that the Mancos Shale only occurs at the GTO pit. This would result in the acquisition of three rather than nine data points for the Mancos Shale. BLM accepts this situation with the reservation that it would base any further requirements for additional Mancos

Shale testing on the testing results from these three Mancos samples and from Summo's current preliminary MWMP testing of a Mancos sample.<sup>1</sup> Based on company information, (i.e., four waste-rock types present at GTO, and three waste-rock types present at both Centennial and Sentinel pits), this sampling program would result in a total of 30 samples.

### **Test Methods**

**Preliminary Solid-Phase Analysis** - The waste-rock units will be sampled as described above, and the resulting samples subjected to solid-phase analysis for antimony, arsenic, cadmium, copper, molybdenum, selenium, uranium and zinc (ROD, p. 23).

**MWMP** - The MWMP testing will be performed on samples collected from the four waste-rock types by the reverse-circulation drilling program as proposed by Summo, and as illustrated in Figure 1 of the August 26, 1997 memorandum from Bill White to Lynn Jackson (copy attached).

**Up-flow Column Test** - Based on data from the Summo's preliminary MWMP testing of a Mancos Shale sample, anticipated poor recovery of MWMP leachant did not occur (BLM was concerned that possible presence of bentonite in the Mancos would inhibit leachant infiltration of the sample and subsequent leachant recovery during the column leach portion of the MWMP test). Because of BLM's initial concern, the up-flow column test was recommended to measure amount of leachant infiltration and recovery under conditions closer to possible field conditions. However, because the anticipated problem did not occur, the up-flow column tests will be postponed until BLM and Summo can jointly review the results of the MWMP tests on three additional Mancos Shale samples that will be collected from the reverse-circulation drilling program. Soil attenuation testing might be substituted for the up-flow column testing (this option is based on consultation with the South Dakota Department of Environment and Natural Resources). Selection of any additional testing methods will be contingent upon a review of the solid-phase chemistry and MWMP data.

## **2- Navajo Aquifer Characterization Test Wells**

In addition to the geochemical testing of waste rock identified above, Summo will conduct additional test drilling of the Navajo aquifer for initial characterization purposes. Water samples from 4 test wells will be collected and analyzed for the same set of parameters as those for previous wells, including MW96-7B (see Table 3.2-4, FEIS, for the minimum set of required parameters). Water quality data from the 4 wells, along with existing data from MW96-7B, will be used to "characterize" (i.e. classify as Class I, II, or III) Navajo aquifer water in the project area. The formal classification of the Navajo aquifer is under the jurisdiction and authority of the State of Utah Department of Environmental Quality, Division of Water Quality (UDEQ). The location of these wells are identified as follows and are intended to provide an analysis of the Navajo aquifer across the project site. Any determination of the acceptability

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<sup>1</sup>Preliminary samples from each of the four rock types have been subjected to MWMP for a "ball-park" idea of their leaching performance under MWMP conditions. Results are pending.



of these wells as long-term compliance monitoring wells will also be under the jurisdiction and authority of UDEQ.

- Sec 26: NESENE T 30 S, R 25 E (Sentinel Pit downgradient)
- Sec 25: SESWSE T 30 S, R 25 E (Centennial Pit downgradient, east side of fault)
- Sec 36: NWNENW T 30 S, R 25 E (Centennial Pit downgradient, west side of fault)
- Sec 6: NE T 31 S, R 26 E (GTO Pit downgradient)

### Notification of Activities

The company will notify BLM in writing, at least 3 days prior to commencement of activities, when the drilling program to collect the waste-rock samples and aquifer test wells is to commence. We realize two of the aquifer test wells are currently underway, and the following information can be provided for these wells "after the fact". Such notification is to include a map of well and test site locations, depths of projected tests, and an estimate of time required to complete the drilling, perform the testing and analyses required, and prepare the resulting data for review. One letter with the required information for all wells and tests will suffice.

As previously indicated in this correspondence, we have included as an attachment a memorandum dated August 26, 1997 from Bill White, BLM Principal Investigator, to Lynn Jackson, BLM Project Manager. This memorandum outlines recommendations for the additional geochemical testing, and contains details of specific testing requirements to be utilized for the geochemical analysis. This information should be of use to you in clarifying testing procedures to be followed. You may note that the number of geochemical samples identified in the August 26 memorandum differs from the number of samples required under this correspondence. You are to follow instruction in this correspondence as to the number of required samples.

Thank you for your diligence on this matter. Please continue to work closely with Bill White in our Utah State Office and Lynn Jackson and Jim Harte on my staff. We look forward to seeing the results of testing.

Sincerely,

/s/ Katherine Kitchell  
Moab District Manager

### Attachments (1)

Internal BLM Memorandum, dated August 26, 1997 (14 pp)

cc: Pat Gochmour, Gochmour and Associates, (w/attachment)  
John Steiger, USDO/Office of the Solicitor, (w/attachment)  
Lowell Braxton, State of Utah/UDOGM, (w/attachment)  
Dennis Fredricks, State of Utah/UDEQ, (w/attachment)  
Bill White, USDO/BLM, (w/attachment)

ALJackson:alj:9/25/97





# United States Department of the Interior

## BUREAU OF LAND MANAGEMENT

Utah State Office  
P.O. Box 45155  
Salt Lake City, UT 84145-0155

DOGM RECEIVED  
SEPT. 29, 1997

M/037/088

August 26, 1997

### Memorandum

To: Lynn Jackson, Project Manager Lisbon Valley Project FEIS

Through: Kate Kitchell, Moab Field Office Manager  
Deputy State Director, Resources, Utah State Office  
Group Leader, Solid Minerals, Utah State Office

From: Principal Investigator, Chemical-Predictive Modelling of Acid Mine Drainage

Subject: Requested Suggestions for Backfill-Related Waste-Rock Leaching Tests

As you requested, I have prepared some suggestions for geochemical testing of waste rock proposed for backfill material. I hope this information is helpful to you and the company.

Although I have received a pit backfilling schedule from the company, I am still confused as to which units are proposed for backfill material. According to my understanding of Summo's FAXed tables (July 29, 1997)<sup>1</sup> and the FEIS (pp. 3-8, 3-9):

- Mancos Shale bed no. 2, Dakota Formation beds 3-5 (sandstones), and Burro Canyon Formation bed 14 (red and green shale, limestone, chert and conglomerate) are possible ANP waste rock units that could potentially make up some of the backfill material,
- Dakota Formation beds 11-13, and Burro Canyon Formation bed 15 are ore, and,
- Dakota Formation, beds 6-10 are the AGP waste rock.

To eliminate confusion, BLM should require quantification of tonnage by rock type that is being proposed to be backfilled in each pit (i.e., tons of Mancos Shale, and other formation facies/beds, etc. per each pit). Further, BLM should also require testing of the proposed backfill material to reasonably evaluate the proposal.

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<sup>1</sup>Two un-numbered tables entitled "Lisbon Valley Copper Project - Pit Backfilling Scenario", and "Lisbon Valley Copper Property, AGP/ANP Determinations By Formation - Drill Samples form within Proposed Pits".



## Waste-Rock Samples

Wherever possible for cost-saving purposes, I have recommended that samples and information be obtained from past exploration activities or from already-planned monitoring and de-watering well development. Rock-type samples for testing are expected to be representative of those rock types proposed for backfill material and are to be segregated by rock type. To better assure a representative distribution of contaminant-element concentrations in each rock type, at least three samples from correlative waste-rock units should be obtained from the following sources:

- Existing pulps from exploration drill holes
- Drill cuttings from planned Navajo monitoring wells and de-watering wells

## Test Methods

**Preliminary Solid-Phase Analysis** - All waste-rock units proposed to be used for backfill material should be sampled as described above, and the resulting samples subjected to solid-phase analysis for arsenic, cadmium, copper, molybdenum, selenium, uranium and zinc (ROD, p. 23). Based on literature-search information (Appendix A), As, Mo, Se, and U form complexes that can be mobilized under alkaline conditions.

Table 1. - Respective groundwater quality standards (GWQ Std), protection levels (PL), and ten times protection levels (PL X 10) for arsenic, molybdenum, selenium, and uranium (after UGW370005). Values are ppm.

ELEMENT	GWQ Std	Protection Level (PL)	PL X 10
Arsenic	0.05	0.025	0.25
Molybdenum	ND	ND	NAP
Selenium	0.05	0.025	0.25
Uranium	0.02	0.02	0.2

ND Not Determined

NAP Not applicable

A preliminary threshold value of ten times the protection level is proposed for arsenic, selenium, and uranium (assumes 10% of the element is available as extractable). Samples with concentrations equal to or greater than ten times the protection level for one or more of the listed elements must be subjected to meteoric water mobility procedure (MWMP) testing.

No groundwater quality standard has been determined as yet for molybdenum. However, according to Smith and others (1996), "irrigation of alkaline soils developed from Cretaceous-age shales in the western United States may increase mobility and transport of Mo, resulting in higher amounts of Mo in agricultural soils, crops, and wetland sediments and biota." Shacklette and Boerngen (1984) reported a geometric mean of 0.85 mg/kg and a range of less than 3 mg/kg to



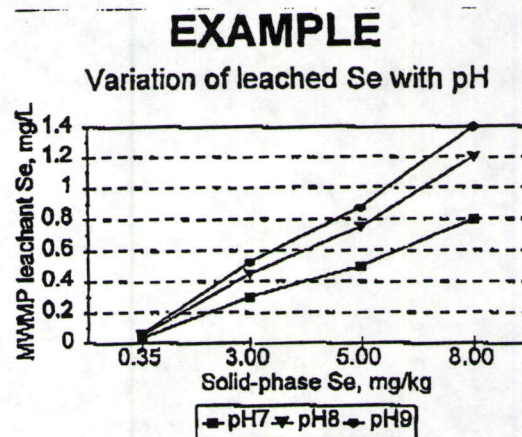
7 mg/kg total Mo for soils from the western United States. Until more definitive data are available for Mo, it seems reasonable to me to select the high end of this range as the preliminary threshold value for solid phase molybdenum concentration. Therefore, analytical results for any sample of waste rock proposed for backfill material that equals or exceeds 7 ppm Mo will be subjected to MWMP testing.

**MWMP** - The Meteoric Water Mobility Procedure (MWMP) test is recommended over the Synthetic Precipitation Leaching Procedure (SPLP) test because it tests a sample that is 50 times larger than the sample tested by SPLP (i.e., 5000 grams versus 100 grams). Additionally, MWMP leachant pH can be adjusted to match the alkaline pH typical of the site rather than being arbitrarily adjusted to pH 5.0. Although the MWMP leachant volume is greater than SPLP leachant volume (5 liters versus 2 liters), the liquid to solid ratio is 1 to 1 for MWMP as compared to 20 to 1 for SPLP. MWMP provides a "worse-case" test that optimizes chances to obtain detectable amounts of leached elements. The method is currently being standardized under the auspices of the Society for Testing and Materials (ASTM).

MWMP should be performed on at least three samples of each waste-rock type using three separate leachants with their respective pH values adjusted to 7, 8, and 9<sup>2</sup> with sodium bicarbonate.

The objective of the proposed test is to quantify how contaminant-element release varies by rock type as a result of changes in leach pH and solid-phase contaminant-element concentration (Figure 1). The value of such a test is identification of the contaminant-element threshold concentration (in the solid-phase), below which the corresponding protection level is not exceeded in the resulting test effluent.

I recommend that plots similar to Figure 1 be prepared for each waste-rock type proposed as backfill material. Each waste-rock unit should have a separate plot for each contaminant element.<sup>3</sup> Because arsenic and selenium have been reported in site groundwater samples, BLM should require that their respective solid-phase forms (i.e., selenate/selenite and arsenate/arsenite) are identified for each backfilled waste-rock type.



**Figure 1.** - Conceptualized plot of solid-phase selenium concentration in four samples of "X" rock type, versus resulting MWMP-leachant selenium concentrations from three NaHCO<sub>3</sub> leaches of pH 7, 8, and 9.

<sup>2</sup>pH values observed for surface and groundwater samples ranged from about 7 to 9 (FEIS, tables 3.2-1 and 3.2-3).

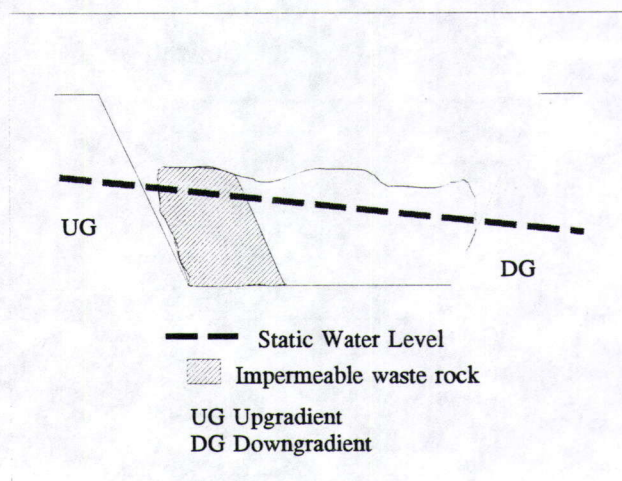
<sup>3</sup>Ensure that the investigated contaminant suite includes arsenic, molybdenum, selenium, and uranium.



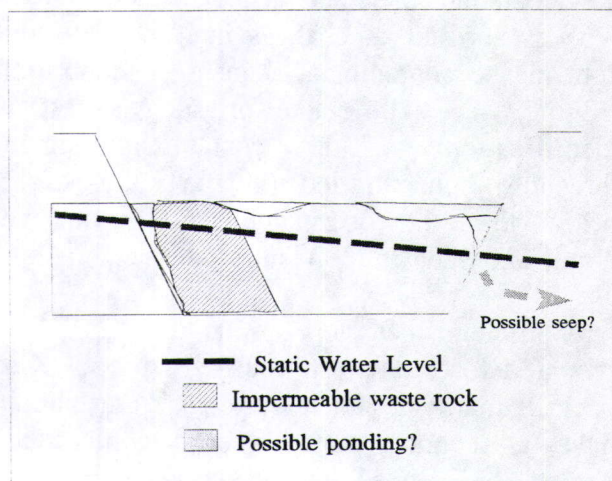
**Up-flow Column Test** - If MWMP tests show that contaminant-element concentrations are equal to or greater than established protection levels for a particular waste-rock unit, then an up-flow column-leach test should be performed to quantify:

- expected amount of leachant infiltration into less permeable waste-rock types such as bentonitic shales (e.g., Mancos Shale, and shale facies in the Burro Canyon and Morrison formations), and
- amount of contaminants (including TDS) actually released, expressed as mg/kg of waste rock.

I have a concern regarding the permeability of bentonitic formations (e.g., Mancos Shale and some facies in the Burro Canyon) that may or may not be relevant to the backfilling proposal. If an up-flow column test demonstrates that bentonitic units have little or no permeability, what happens to the upgradient groundwater flow into the pit? Does the upgradient side of an impermeable backfill act as a dam (Figure 2A) which consequently raises the level of upgradient saturation until it "spills over the top of the dam" (Figure 2B - is this hydrologically possible)? Could water actually pond on top of the backfill as a result of placement of impermeable waste rock against the upgradient highwall? What would happen to this ponding? Would it seep into the downgradient highwall so that the pond depth never exceeds the top of the upgradient dam?



**Figure 2A.** - Backfilled pit with impermeable waste rock adjacent to upgradient highwall.



**Figure 2B.** - Possible "dam" effect caused by impermeable waste rock (with consequent groundwater impoundment behind "dam") and subsequent ponding on backfill surface.

If this is a valid concern, then regardless of the amount of contaminant release, the recommended up-flow test should be performed on the Mancos Shale because it has been identified by the company as the bulk of the backfill waste rock.

### Estimated Test Cost

**Solid-phase Analysis** - Profile II analyses range from \$333 to \$363<sup>4</sup> per sample. Chemex Labs Ltd.<sup>5</sup> recommends that uranium be determined by neutron activation analysis (NAA); cost per sample is \$4.50.

**MWMP Test** - Cost per sample to perform the 24-hour leach and effluent analyses (i.e., primary and secondary drinking water standards) ranges from \$410<sup>6</sup> to \$435.<sup>7</sup> If three leaches (i.e., pH 7, 8, and 9, respectively) are performed on three samples per waste-rock type, the cost per waste-rock type to generate the data for a plot such as Figure 1 ranges from \$3690 to \$3915.

**Up-flow Column Test** - Cost per sample to perform a four-week up-flow column test is approximately \$8300.<sup>4</sup> The four-week period is based on time required to load the column and to pump one pore volume through the rock mass. Pump rates are based on estimated recharge rates for the GTO, Centennial, and Sentinel pits (33, 29, and 18 gpm, respectively - ABC, October 13, 1996, p. 23).

Should you have questions or need additional information, I can be reached by phone at (801) 539-4039, or via Internet address, b1white@ut.blm.gov.

W. W. White III, P.G.

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<sup>4</sup>Telephone communication, August 27, 1997 with Karl McCrea, American Assay Laboratories, (702)356-0606

<sup>5</sup>Telephone communication, August 27, 1997 with Brenda Caughlin, Chemex Labs Ltd., (604)984-0221

<sup>6</sup>Telephone communication, August 11, 1997 with Clayton Chappell, McClelland Laboratories, (702)356-1300

<sup>7</sup>Telephone communication, August 22, 1997 with Karl McCrea, American Assay Laboratories, (702)356-0606 (cost includes acid-base accounting - total S and ANP)



## **APPENDIX A**

### **MOBILIZATION OF SPECIFIC ANIONS UNDER ALKALINE CONDITIONS**



## Sources of As, Mo, and Se in Sedimentary Rocks

### Anomalous Mo and Se in Cretaceous-aged Shales

According to Lawton (1955, p. 72) and Smith and others (1997, p. 27), soils developed from certain Cretaceous-aged shales in the western United States tend to contain concentrations of selenium (Se) and molybdenum (Mo) that exceed background values typically listed for shales and soils. Although arsenic (As) is found in relatively high concentrations in shales and clays, and in significant quantities in coal and coal fly ash (National Academy of Sciences - NAS, 1977, pp 49-50), I could find no data on arsenic content specifically tied to Cretaceous shales or related soils (Table A-1).

Table A-1. - Crustal concentrations of arsenic, molybdenum, and selenium compared with their respective average concentrations in specific rock types and soils.

Element	Average Concentration, ppm						
	Crust <sup>1</sup>	Shale	Limestone	Sandstone	Coal	Soil	K shale
As	1.5-2 <sup>2</sup> 1.8 <sup>3</sup>	14.5 <sup>2</sup> 15 <sup>3</sup>	2.6 <sup>2</sup> 2.5 <sup>3</sup>	4.1 <sup>2</sup>	15 <sup>2</sup>	7.2 <sup>2</sup>	ND
Mo	1.5 <sup>3</sup>	3 <sup>3</sup>	1 <sup>3</sup>	ND	ND	2 <sup>3</sup>	<3-7 <sup>4</sup>
Se	0.05-0.09 <sup>5</sup> <0.1 <sup>6</sup>	0.60 <sup>5</sup>	0.08 <sup>5</sup>	0.05 <sup>5</sup>	3.0 <sup>5</sup>	<0.1-2 <sup>5</sup>	1-6 <sup>5</sup> 2-10 <sup>7</sup>

<sup>1</sup>Crustal/Terrestrial concentration

K Cretaceous

<sup>2</sup>National Academy of Sciences, 1977, Table 2.3

<sup>3</sup>Levinson, 1974, Table 2-1

ND No data available

<sup>4</sup>Smith and others, 1997, p. 27

<sup>5</sup>Chapter 12, Selenium, pp. 390-420

<sup>6</sup>Mitchell, 1955, p. 281

<sup>7</sup>Lawton, 1955, p. 72

### Ranges of As, Mo, and Se Values in Shales

Based on data summarized in Table A-1, Mo and Se concentrations in Cretaceous shales are respectively, 2.3 and nearly 17 times average concentrations for shale, and 3.5 and 5 times average concentrations for soil. Arsenic concentrations for typical shale and coal are 7 to 10 times crustal concentrations. No documented As concentrations were listed for Cretaceous shales in the published sources I had available for this review.



## Possible Relationship of Bentonite with Anomalous Se in Cretaceous Shales

In the western United States, the most highly seleniferous sediments were deposited in shallow Cretaceous seas. The origin of the selenium has yet to be conclusively determined. However, according to NAS (1976, p. 11), researchers observed high levels of selenium in Hawaiian iron-bearing volcanic soils associated with adjacent volcanic vents whose gases also contained selenium. They concluded that selenium contained in these soils was derived mainly from volcanic gases and their sublimates which were subsequently mobilized, transported and sorbed to the adjacent iron-bearing soils during seasonal heavy rains. These same researchers extended this hypothesis of selenium volcanic origin to sedimentary rocks of the continental United States. Specifically, they concluded that bentonite deposits (which are commonly the product of chemically-weathered water-laid air-fall volcanic tuffs) precede, accompany, and follow selenium deposition in Cretaceous-aged sedimentary rocks. NAS (1976, p. 11) further stated that "...volcanic tuffs and volcanic sulfur of very high selenium content have been reported, lending credence to the volcanic origin theory..."

### As, Mo, and Se in Cretaceous-age Mancos Shale, Utah

Only two reports were available to me that quantify As, Mo, and Se concentrations in Utah deposits of Mancos Shale. Although the data from these reports are limited, they give us an idea of possible As, Mo, and Se concentration ranges present in the Mancos Shale. The data are summarized in Table A-2.

Table A-2. - Arsenic, molybdenum, and selenium concentrations in Mancos Shale soil samples collected from various Utah locations.

SAMPLE	Concentration, mg/kg		
	Arsenic	Molybdenum	Selenium
1994 BLM Study - Cisco Desert: <sup>1</sup>			
12-US-2	4.5	10	0.38
12-US-3	6.1	10	0.29
1933-35 USDA Study - Tech Report 482: <sup>2</sup>			
N14x - 1mi east of Jensen, UT	ND	ND	5
N15y - 6 mi east of Jensen, UT	ND	ND	3
N3x - 6 mi west of Cisco, UT	ND	ND	8
N24x - 1.5 mi west of Desert Switch, UT	ND	ND	0.2

<sup>1</sup>ELI, 1994, Analytical report

<sup>2</sup>Byers, 1935, Table 24, p. 35

ND No data available



An unpublished ELI study (1994) of two Mancos-Shale derived soils from Sager's Reservoir #12, Cisco Desert was performed under a BLM contract. The two soil samples were tested using a modified EPA 1312 leaching method. Test protocol with modifications and analytical results are contained in Appendix B. Resulting data from samples 12-US-2 and 12-US-3 show that they contain As concentrations that are up to three times crustal concentrations, but are less than half of typical shale and coal concentrations. By contrast, their Mo concentrations (10 ppm) slightly exceed published Cretaceous-shale Mo concentrations, while their Se concentrations are an order of magnitude less than published Cretaceous-shale Se concentrations (see Table A-1).

A 1933-35 study of Se occurrences in western United States soils was conducted by the U.S. Department of Agriculture, and published as USDA Technical Bulletin Nol 482 (Byers, 1935).

As part of the study, Se concentrations were determined from four Mancos-Shale derived soil samples collected from the Jensen and Cisco, UT vicinities (Table A-2). The Jensen area samples (N14x and N15y) contained Se concentrations that were respectively, an order of magnitude greater than crustal concentrations, 5 to 8 times typical shale concentrations, and within reasonable agreement with the published range of Cretaceous shale Se concentrations. The Cisco sample (N3x) Se concentration was also an order of magnitude greater than crustal concentrations, 13 times typical shale concentrations, and was at the high end of the published range for Cretaceous shale Se concentrations. The Desert Switch sample (N24x) Se concentration was only slightly above crustal concentrations, 1/3rd of typical shale concentrations, and an order of magnitude less than the published range for Cretaceous shale Se concentrations.

### **Association of Mo and Se with uranium in sedimentary rocks**

According to Grunig (1981, p 18), molybdenum and other elements such as vanadium, selenium, and tellurium tend to be concentrated along with uranium in reduced zones in sedimentary rocks. Hem (1989, p. 145) stated that selenium minerals such as ferroselite ( $\text{FeSe}_2$ ) are associated with some uranium ore deposits in sandstones of the western United States. Smith and others (1996, pp. 26) cited examples of molybdenosis<sup>8</sup> that may have resulted from stock grazing 1) near a lignite ashing plant, 2) in an area of uranium mining, 3) near clay mining, and 4) at a uranium-bearing lignite area; Mo problems were not known to exist in these areas before mining and mineral processing began.

### **Mobilization of As, Mo, and Se**

#### **Soil pH**

Retention and mobility of metals in soil is a function of soil pH. Soil pore-water pH is a controlling factor in adsorption-desorption reactions and precipitation-solubilization reactions. Additionally, the cation exchange capacity of soils generally increases with an increase in pH. Even with a soil that has a high affinity for a specific metal, the degree to which the metal is fixed is a function of pH (Canter and others, 1987, pp.155-156).

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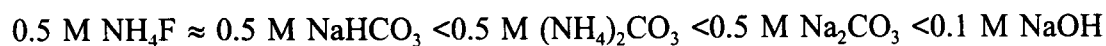
<sup>8</sup>A condition in livestock resulting from high concentrations of Mo and S [not quantified] and low amounts of Cu in forage.

For example, Frost and Griffin (1977) studied the effect of pH on the adsorption of arsenic and selenium anions from municipal sanitary landfill leachate. The results suggested that disposal of arsenic and selenium wastes in municipal landfills, especially under alkaline conditions, could produce ground water contamination by these two metals.

**Selenium** - Soluble selenates would be expected in alkaline soils or alkaline weathering rocks in dry areas. According to NAS (1976, p. 2), because of selenate stability at alkaline pH, its solubility, and its ready availability to plants, selenate appears to be the most dangerous form of selenium as far as potential environmental pollution is concerned.

**Molybdenum** -According to Smith and others, (1996, p. 27) irrigation of alkaline soils developed from Cretaceous-age shales may increase mobility and transport of Mo, resulting in higher amounts of Mo in agricultural soils, crops, and wetland sediments and biota. The availability of Mo to plants is largely dependent on soil pH. Mo availability in soils is greatest under alkaline conditions and least under acidic conditions. This behavior of Mo in the surficial environment is related mainly to its tendency to form dissolved anionic species (Smith and others, 1996, pp. 32-33).

**Arsenic** - NAS (1977, p. 62) suggests that As mobility increases as pH increases, especially if pH is adjusted by liming. The calcium ion present as the principal constituent of lime combines with  $(As^{(V)}O_4)^{2-}$  to form a calcium arsenate that is more soluble than the iron or aluminum counterparts of the arsenate complex. Additionally, NAS (1977, pp. 52-53) summarized the efficiency of basic extractants to remove extractable arsenic from soil and showed that extractant effectiveness increases with increasing pH:



### **Adsorption and Desorption of Anions**

Anion adsorption (such as As, and Se) on oxide surfaces is also dependent on pH, but in contrast to cations, adsorption is generally greater at lower pH values and decreases with increasing pH (Davis and Kent, 1990, pp. 199).

Figures 13b and 13c (from Davis and Kent, 1990, pp. 200-201) shows the percent adsorption of some As and Se anions on ferrihydrite (i.e., poorly crystalline hydrous ferric oxide) as a function of pH, oxidation state, and ionic strength. Note that at pH 8 practically all of the Se(VI), and 60% of the As(V) is desorbed from the ferrihydrite.

## **BASIS FOR CONCERN REGARDING BACKFILL**

The Lisbon Valley site exhibits the following general characteristics; these characteristics are similar to those described in the preceding discussion of conditions and mechanisms required to mobilize oxyanions of such elements as arsenic, molybdenum, and selenium.

- Bentonitic shales are present at the site (Mancos Shale and shale facies in Burro Canyon Fm - Katich, 1958, p. 194).



- Levels of As, Mo, and Se that either approach drinking water standards or exceed detection limits by an order of magnitude are present in groundwater samples from some on-site monitoring wells (see Appendix C).
- Samples of site groundwater and surface water have pH values that range from 7 to 9 (FEIS, tables 3.2-1 and 3.2-3).
- Bicarbonate alkalinity is present in surface and groundwater samples (FEIS, tables 3.2-1 and 3.2-3).
- The site is within the largest uranium mining district in Utah (FEIS, p. 3-19).

Additionally, overburden and waste rock placed in a backfill will usually be characterized by reduction in particle size and subsequent increase in surface area due to blasting and excavating. If the backfill material is placed within the influence of the groundwater table, 1) the increased surface area of the excavated material commonly results in increased mineral-water interface contact, and 2) may result in consequent mineral dissolution and transport by groundwater movement through the backfill. Depending upon the chemistry and permeability of waste-rock types comprising the backfill, possible infiltration of groundwater into these materials has potential to produce the unintended consequence of mobilizing such elements as arsenic, molybdenum and selenium as oxyanions.

## REFERENCES

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**APPENDIX B**

**ANALYSIS OF TWO MANCOS SHALE DERIVED SOILS FROM SAGER'S  
RESERVOIR #12, CISCO DESERT, UTAH**

## TECHNICAL PROPOSAL; METHODOLOGY

As this project is somewhat unique in scope, the following discussion presents ELI's anticipated technical approach to the soil analysis. It is ELI's understanding that BLM is interested in gathering data on soluble salt loading in Colorado River Basin soils and sediments. In order to determine the gross quantity of soluble inorganic chemical species in the soil samples, a modified EPA 1312 method can be employed. The deviations from the published method include varying the solid to liquid ratios as will be further discussed, increasing the extraction time, and eliminating the sulfuric acid addition to the extraction solution.

ELI, therefore, presents the following as a procedure to determine soluble salts in soils. Following a 24 hour extraction period during which the samples are tumbled at 30 revolutions/minute, the fluid will be extracted by vacuum filtration. Total dissolved solids and conductance determinations would be performed on each extract. Based upon previous work on the Moab BLM samples, full solubilization of chemical species was found to be achieved on a 1:20 solid/liquid ratio.

For convenience, the 1312 extraction time would be extended to 24 hours. Two liter or larger plastic containers will be used for the extraction. Tumbling rates of 30 revolutions per minute will be utilized for all samples to assure identical treatment. The extraction equipment is located in a temperature controlled area to assure all samples will be equally extracted. Analysis techniques for the extracts will be USEPA equivalents of the USGS National Handbook methods and these are identified in the following table.

All samples will be prepared using the following protocol.

1. All sub-samples will be collected from the entire volume of the soil sample (excluding rocks) which will be shipped in one gallon ziplock bags by BLM-Moab.
2. The entire volume of soil will be dried at  $-40^{\circ}\text{C}$
3. The entire sample will be pulverized (excluding rocks) and blended into a homogeneous mixture.
4. The volume of soil required for the test will be collected from a riffle splitter and duplicate samples will also be collected from the splitter.
5. Samples requiring "Percent Acid-Soluble Salts by Weight" will be subjected to an extraction technique referred to as EPA-SW846-3050. In this technique a known mass of split soil sample is heat digested in a mixture of concentrated nitric acid and hydrogen peroxide. The resultant fluid is separated from the insoluble portion by vacuum filtration and diluted to a known volume. Specific analytes as outlined in Table II would be quantified on the extract. The sum of these analytes and carbonates will be provided as % Acid-Soluble Salts.



TABLE II: ANALYTICAL METHODOLOGY

Parameter	Method Code	Technique	ELI's LLD Units	
Category I - Analysis Physical Parameters				
Performed on Method 1312 Extract				
3AA % Soluble Salts by Weight	EPA-160.1	Gravimetric	0.0001	%
3AC Conductivity	USGS HB 60	Wheatstone Bridge	1.0	umhos/cm
Category II - Acid Soluble Salts Constituents				
Performed on Method SW-3050 Extract				
3AC Carbonates	USDA HB 60	Method 23C Acid Neutral	1000	mg/kg
3AC Chloride	EPA-200.7	Simultaneous ICP	100	mg/kg
3AC Sulfate	EPA-200.7	Simultaneous ICP	100	mg/kg
3AC Calcium	EPA-200.7	Simultaneous ICP	10.0	mg/kg
3AC Magnesium	EPA-200.7	Simultaneous ICP	1.0	mg/kg
3AC Potassium	EPA-200.7	Simultaneous ICP	10.0	mg/kg
3AC Sodium	EPA-200.7	Simultaneous ICP	10.0	mg/kg
3AC Aluminum	EPA-200.7	Simultaneous ICP	5.0	mg/kg
3AC Arsenic	EPA-206.2	Hydride generation AA	1.0	mg/kg
3AC Barium	EPA-200.7	Simultaneous ICP	5.0	mg/kg
3AC Beryllium	EPA-200.7	Simultaneous ICP	1.0	mg/kg
3AC Cadmium	EPA-200.7	Simultaneous ICP	1.0	mg/kg
3AC Chromium	EPA-200.7	Simultaneous ICP	1.0	mg/kg
3AC Cobalt	EPA-200.7	Simultaneous ICP	1.0	mg/kg
3AC Copper	EPA-200.7	Simultaneous ICP	1.0	mg/kg
3AC Iron	EPA-200.7	Simultaneous ICP	5.0	mg/kg
3AC Lead	EPA-200.7	Simultaneous ICP	1.0	mg/kg
3AC Manganese	EPA-200.7	Simultaneous ICP	1.0	mg/kg
3AC Molybdenum	EPA-200.7	Simultaneous ICP	1.0	mg/kg
3AC Nickel	EPA-200.7	Simultaneous ICP	5.0	mg/kg
3AC Selenium	EPA-270.3	Hydride Generation AA	0.10	mg/kg
3AC Strontium	EPA-200.7	Simultaneous ICP	5.0	mg/kg
3AC Vanadium	EPA-200.7	Simultaneous ICP	5.0	mg/kg
3AC Uranium	EPA-200.7	Simultaneous ICP	50.0	mg/kg
3AC Zinc	EPA-200.7	Simultaneous ICP	1.0	mg/kg



**ENERGY LABORATORIES, INC.**

P.O. BOX 3258 • CASPER, WY 82602 • PHONE (307) 235-0515  
254 NORTH CENTER, SUITE 100 • CASPER, WY 82601 • FAX (307) 234-1639

**LABORATORY ANALYSIS REPORT – Bureau of Land Management – Moab**

Report Date: 03-27-95

Sample I.D.:

Sample Number:

12-US-2	12-US-3
94-62199	94-62200

**Major Ions**

**Units**

**Results**

**Results**

**Det. Limit**

Calcium	Ca	mg/kg
Magnesium	Mg	mg/kg
Sodium	Na	mg/kg
Potassium	K	mg/kg
Calcium Carbonate	CaCO <sub>3</sub>	%
Sulfate	SO <sub>4</sub>	mg/kg
Chloride	Cl	mg/kg

60990	46455
14725	14345
114	114
1159	1026
17.0	15.1
32965	20330
152	133

100
100
100
100
0.10
100
100

**Trace Metals**

Aluminum	Al	mg/kg
Arsenic	As	mg/kg
Barium	Ba	mg/kg
Beryllium	Be	mg/kg
Cadmium	Cd	mg/kg
Chromium	Cr	mg/kg
Cobalt	Co	mg/kg
Copper	Cu	mg/kg
Iron	Fe	mg/kg
Lead	Pb	mg/kg
Manganese	Mn	mg/kg
Molybdenum	Mo	mg/kg
Nickel	Ni	mg/kg
Selenium	Se	mg/kg
Strontium	Sr	mg/kg
Vanadium	V	mg/kg
Zinc	Zn	mg/kg

4171	3553
4.47	6.08
27.6	16.2
< 1.0	< 1.0
< 1.0	< 1.0
8.6	7.6
3.8	3.8
10.5	9.5
11115	9785
10.5	12.4
161	127
< 10.0	< 10.0
13.3	9.5
0.38	0.29
80.8	81.7
12.4	10.5
43.7	39.9

10.0
0.10
10.0
1.0
1.0
5.0
1.0
1.0
5.0
5.0
1.0
10.0
0.05
0.10
10.0
10.0
1.0

**Radiometric**

Uranium	U – Nat	mg/kg
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< 100	< 100
-------	-------

100
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Report Approved by:

*P.A. Harding*

PIM 62164blm.wk3



Eight monitoring wells were initially installed by the company. Sampling frequency for six of the eight wells was from 7 to 8 times during the October 1994 through June 1996 period. Well 95R1 was sampled once before being plugged, and well 94MW4 was sampled four times during the August 1995 through June 1996 period (FEIS, Table 3.2-3).

Elevated concentrations of arsenic, molybdenum, and selenium that approach drinking-water standards, and concentrations of antimony, cadmium, and zinc that exceed drinking-water standards (DWS) occur in some quarterly samples from six monitoring wells listed in Table C-1:

Table C-1. Water-sample concentrations for selected elements from Lisbon Valley Project monitoring wells (from WWC 8/19/96 RPT/2)

MONITOR WELL	Analyte concentrations (mg/L); respective primary drinking water standards listed in parentheses						AQUIFER
	As (0.05)	Sb (0.006)	Cd (0.005)	Mo (NL)	Se (0.05)	Zn (5.0) <sup>1</sup>	
SLV1A			0.029 4/95 0.021 5/95 0.014 8/95 0.009 11/95 0.007 4/96 0.008 6/96	0.019 6/69	0.015 8/95 0.018 4/96	5.2 5/95 1.4 11/95	Burro Cyn
SLV3	0.04 5/95				0.032 8/95 0.012 4/96		Burro Cyn
MW2A					0.016 8/95		Burro Cyn
94MW2		0.007 10/94 0.007 8/95	0.009 5/95 0.018 8/95 0.012 11/95 0.011 4/96 0.005 6/96	0.48 10/94 0.57 4/95	0.027 3/95 0.014 8/95		Burro Cyn
94MW4		0.013 8/95 0.005 4/96 0.003 6/96					Honaker Tr
94MW6					0.017 3/95		Mancos Sh

NL No primary or secondary drinking water standard listed

<sup>1</sup>Secondary drinking water standard

- Cadmium concentrations exceed DWS from all sample periods for SLV1A and 94MW2.
- Antimony concentrations exceed DWS from two sample periods for 94MW2, and from one of three sample periods for 94MW4.
- Zinc concentrations exceed DWS from one of two sample periods for SLV1A.

- Selenium concentrations are an order of magnitude greater than detection limits (0.002-0.008 mg/L), and from 1/3 to 2/3 of DWS concentrations for SLV1A, SLV3, MW2A, 94MW2, and 94MW6.
- Molybdenum concentrations are an order of magnitude greater than detection limits (0.001-0.005 mg/L) for SLV1A and two orders of magnitude greater for 94MW2.